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MIXER CIRCUIT
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[Claims]

[Claim 1] A mixer circuit that is an even harmonic mixer circuit that utilizes an antiparallel diode mixer, said mixer being characterized by the fact that an input terminal for a first frequency signal is connected to one terminal of the aforesaid antiparallel diode mixer, while an input/output terminal for a second frequency signal is connected to the other terminal, and that the aforesaid one terminal has an input/output terminal for a third frequency signal also connected to it, while the aforesaid other terminal is grounded for the third frequency and direct current.

[Claim 2] The mixer circuit stated in Claim 1, wherein the aforesaid one terminal is grounded for direct current.

[Claim 3] A mixer circuit that is an even harmonic mixer circuit that utilizes an antiparallel diode mixer, said mixer being characterized by the fact that an input terminal for a local oscillator frequency signal is connected to one terminal of the aforesaid antiparallel diode mixer, while an input/output terminal for an RF frequency signal is connected to the other terminal, and that the aforesaid one terminal has an input/output terminal for an intermediate frequency signal also connected to it, while to the aforesaid other terminal is connected a circuit having sufficiently high impedance at the local oscillator frequency and RF frequency, thereby grounding the terminal for the third frequency and direct current.

[Claim 4] The mixer circuit stated in Claim 3, wherein a circuit having sufficiently high impedance at a local oscillator frequency, RF frequency, and intermediate frequency is connected to the aforesaid one terminal, thereby grounding the terminal for direct current.

[Detailed Description of the Invention]

[0001] [Industrial Field of Application]

The present invention pertains to a mixer circuit used as the frequency-conversion circuit, etc., of transceivers that are used in the microwave bands or millimeter-wave bands. In particular, it pertains to an even harmonic mixer circuit that uses a mixer in which reverse polarity diodes are placed in parallel.

[0002] [Prior Art]

There have been proposed mixer circuits that use a mixer called an antiparallel diode mixer, in which a pair of diodes having opposing polarity are placed in parallel. Fig. 4 is a circuit diagram that illustrates an example of this type of circuit, and this example is the one described in a journal (IEEE TRASACTION [sic] ON MICROWAVE THEORY AND TECHNIWUES [sic], VOL. MTT-23, NO.8, pp 671, **1975**, August.) In this example, the mixer is applied to a RF receiver that outputs an intermediate frequency signal of a microwave band from a local oscillator signal of a microwave band and a received signal of a microwave band.

[0003] In this figure, reference numeral 21 is an input terminal for inputting local oscillator frequency signal fLO and received RF

frequency signal fRX, and 22 is an output terminal for outputting intermediate frequency signal fIF. Between these terminals, a first filter (24), an antiparallel diode mixer (23), and a second filter (25) are directly connected. The first filter (24) is a bandpass filter that allows the local oscillator frequency signal and received RF frequency signal to pass, and the second filter (25) is a bandpass filter whose center frequency is the intermediate frequency. The antiparallel diode mixer (23) is configured by connecting a pair of reverse polarity diodes (D1, D2) in parallel so that they face each other.

[0004] With this mixer circuit, after a local oscillator frequency signal and received RF frequency signal that are input to the input terminal (21) pass through the first filter (24), their frequencies are mixed by the antiparallel diode mixer, and the obtained intermediate frequency signal passes through the second filter (25) and is output from the output terminal (22).

[0005] [Problems that the Invention Intends to Solve]

With a mixer circuit that uses this conventional antiparallel diode mixer, the equivalent circuit of this circuit becomes as shown in Fig. 5 for the intermediate frequency signal generated in the mixer (23) when a received RF frequency signal is input, and it can be seen that the circuit is not grounded in the intermediate frequency band. As a result, the intermediate frequency signal generated in the mixer circuit partially leaks to the input-terminal (21) side.

[0006] In addition, a current generated in the pair of diodes (D1, D2) comprising the mixer (23) runs across both diodes (D1, D2), as shown in Fig. 6, because both ends of the mixer are open; consequently, current i ends up flowing against twice the resistance of one diode, thus increasing its loss. For these reasons, this mixer circuit has a problem in that a loss caused by conversion to the intermediate frequency band in this mixer circuit increases.

[0007] [Objective of the Invention]

The present invention intends to provide a mixer circuit whose conversion loss in frequency conversion is decreased.

[0008] [Means of Solving the Problems]

In the mixer circuit of the present invention, an input terminal for a first frequency signal is connected to one terminal of an antiparallel diode mixer, while an input/output terminal for a second frequency signal is connected to the other terminal, and an input/output terminal for a third frequency signal is further connected to the first-mentioned terminal, under which conditions the other terminal is grounded for the third frequency and direct current. In addition, the first-mentioned terminal is grounded for direct current.

[0009] For example, an input terminal for a local oscillator frequency signal is connected to one terminal of an antiparallel diode mixer, while an input/output terminal for a RF frequency signal is connected to the other terminal, and an input/output terminal for an

intermediate frequency signal is connected to the first-mentioned terminal, while a circuit having sufficiently high impedance at the local oscillator frequency and Rf frequency is connected to the other terminal, thereby grounding the terminal for the intermediate frequency and direct current. In addition, to the first-mentioned terminal is connected a circuit having sufficiently high impedance at the local oscillator frequency, RF frequency, and intermediate frequency, thereby DC-grounding the terminal.

[0010] [Operation]

Since the other terminal of the antiparallel diode mixer is grounded for the third frequency and direct current, the third frequency signal generated in the mixer is reflected and output from the input/output terminal for the third frequency signal. In addition, because both ends of the antiparallel diode mixer are DC-grounded, the direct current electricity generated in the mixer is conducted through only one or the other of the pair of diodes; thus, the diode resistance decreases by half.

[0011] [An Embodiment]

The following explains the present invention, referring to figures. Fig. 1 is a circuit diagram of one embodiment of the mixer circuit of the present invention, and it illustrates an example of configuring the mixer circuit of the present invention as a mixer circuit for converting a received RF frequency signal of the millimeter-wave band into an intermediate frequency signal of the

microwave band with a local oscillator frequency signal of the quasi-millimeter wave. Reference numeral 1 is a local oscillator [LO] input terminal for local oscillator frequency signal fLO; 2, a reception input terminal for received RF frequency signal fRX; and 3, an intermediate frequency output terminal for intermediate frequency signal fIF generated as a result of frequency conversion. To the aforesaid LO input terminal (1) is connected a bandpass-type local oscillator filter (12) whose center frequency is the local oscillator frequency, and to the aforesaid reception input terminal (2) is connected a bandpass-type reception filter (13) whose center frequency is the received frequency. To the aforesaid intermediate output terminal (3) is connected a bandpass-type intermediate frequency filter (14) whose center frequency is the intermediate frequency.

[0012] The remaining ends of the aforesaid LO filter (12) and the intermediate frequency filter (14) are connected to each other, and between this node and the aforesaid reception filter (13) is connected an antiparallel diode mixer (11) comprised of a pair of reverse polarity diodes (D1, D2). One end of this antiparallel diode mixer (11), that is to say, the node of the LO filter (12) and the intermediate frequency filter (14), is grounded by means of a first DC-grounding line (15) (for example, an inductance comprised of strip lines) that has sufficiently high impedance at each of the local oscillator frequency, received frequency, and intermediate frequency. The other end of the antiparallel diode mixer, that is to say, the

node of the intermediate frequency output terminal (3) and the reception filter (13) located on the opposite end, is grounded by means of a second line (16) that is used for grounding the intermediate frequency and direct current and that has sufficiently high impedance at the local oscillator frequency and received frequency.

[0013] This mixer circuit functions as an even harmonic mixer when mixing frequencies. The operation of this even harmonic mixer is described in pp. 673 - 677 of the journal cited previously. Namely, it is a mixer that receives a first frequency signal (f1) and a second frequency signal (f2) and then outputs a third frequency signal (f3) given by Expression 1.

$$f3 = |mf1 \pm nf2| \qquad (1)$$

Here,

$$|m \pm n| = 2k + 1 \qquad (2)$$

(provided that m, n, and k are integers.)

[0014] Generally speaking, in the case of converting an RF frequency signal as the second frequency signal into an intermediate frequency signal as the third frequency signal, it is a common practice to utilize the mixer under the condition of n = 1; therefore, m becomes an even number from Expression 2, and Expression 1 can be rewritten as Expression 3.

$$f3 = |2if1 \pm f2| \qquad (3)$$

(provided that i is an integer.)

[0015] When this even harmonic mixer is used, as is evident from Expression 3, the third frequency signal (f3) can be obtained with the first frequency signal (f1) whose frequency is about 1/2 or less the second frequency signal (f2). Assuming that i = 1, inputting a local oscillator frequency (fLO) as the first frequency signal (f1) and a received RF frequency signal (fRF) as the second frequency signal (f2) into the mixer yields an intermediate frequency signal (fIF) given by Expression 4 as the second [sic] frequency signal.

$$fIF = |2fLO - fRF| \qquad (4)$$

[0016] Here, because, in the mixer circuit shown in Fig. 1, the reception input side of the antiparallel diode mixer (11) is grounded by means of the intermediate-frequency and DC-grounding second line (16) that has sufficiently high impedance at the local oscillator frequency and the received frequency, the equivalent circuit in the intermediate frequency band becomes as shown in Fig. 2, and one end of it is in a grounded state. Therefore, the intermediate frequency signal generated in the mixer (11) is reflected at this ground point and, consequently, is mostly output from the intermediate frequency output terminal (3).

[0017] The RF frequency signal input into the mixer circuit causes direct current to be generated in the antiparallel diode mixer (11). However, because the antiparallel diode mixer (11) has the first and second DC-grounding lines (15, 16) connected to both ends of it,

current i flowing from one end to the other end of the mixer (11) passes through one diode (D1) of the antiparallel diode mixer, as shown in Fig. 3 (a), while a current running in the opposite direction passes through the other diode (D2) of the antiparallel diode mixer (11), as shown in Fig. 3 (b). As a result, a current runs through only one diode in either case, and, compared with the prior-art configuration shown in Fig. 6, the diode resistance decreases by half.

[0018] Thus, intermediate frequency signals are mostly output from the intermediate frequency output terminal (3) as a result of grounding one end of the equivalent circuit of the intermediate frequency band, and the actual resistance of the diodes through which the direct current generated in the mixer (11) is conducted can be reduced by half; as a consequence, it becomes possible to reduce conversion loss in the frequency conversion of intermediate frequency signals.

[0019] In the aforesaid explanation, the mixer circuit of the present invention is configured as a mixer circuit for converting a received RF frequency signal into an intermediate frequency signal with a local oscillator signal in a receiver unit. Conversely, it can be configured as a mixer circuit for mixing an intermediate frequency signal and local oscillator signal to output a RF frequency signal in a transmitter unit, and conversion loss can also be decreased in this case.

[0020] [Effects of the Invention]

As explained in the foregoing, according to the present invention, the input terminal for the first frequency signal and input/output terminal for the third frequency signal are connected to one terminal of the antiparallel diode mixer, while the input/output terminal for the second frequency signal is connected to the other terminal, and the other terminal is grounded for the third frequency and direct current; as a consequence, the third frequency signal generated in the mixer is reflected at this ground point and output through the input/output terminal for the third frequency signal, thereby reducing the conversion loss of the third frequency signal generated in the mixer circuit.

[0021] Furthermore, by DC-grounding one terminal of the mixer, the direct current generated in the mixer is conducted through only one or the other of the diode pair, and, consequently, the diode resistance is reduced by half, thus further decreasing the conversion loss of the mixer circuit.

[0022] For example, to one terminal of the antiparallel diode mixer are connected the terminals for the local oscillator frequency signal and intermediate frequency signal, while a circuit having sufficiently high impedance at the local oscillator frequency and RF frequency is connected to the other terminal so as to ground the other terminal for the intermediate frequency signal and direct current, thereby decreasing the conversion loss of the intermediate frequency

signal. In addition, to one terminal is connected a circuit having sufficiently high impedance at the local oscillator frequency, RF frequency, and intermediate frequency so as to DC-ground this terminal; thus, the diode resistance against the direct current generated in the mixer can be reduced by half, thereby further reducing the aforesaid conversion loss.

[Brief Explanation of the Drawings]

[Fig. 1] A circuit diagram of one embodiment of the mixer circuit of the present invention.

[Fig. 2] A diagram of the equivalent circuit of the mixer circuit for intermediate frequency signals.

[Fig. 3] A drawing illustrating the flow of the current generated in the mixer.

[Fig. 4] A circuit diagram of one example of a mixer circuit that employs a conventional even harmonic mixer.

[Fig. 5] A diagram of the equivalent circuit for intermediate frequency signals in the mixer circuit shown in Fig. 4.

[Fig. 6] A drawing illustrating the flow of the current generated in the mixer circuit shown in Fig. 4.

[Explanation of Reference Numerals]

1 LO input terminal

2 reception input terminal

3 intermediate frequency output terminal

11 antiparallel diode mixer

12 LO filter

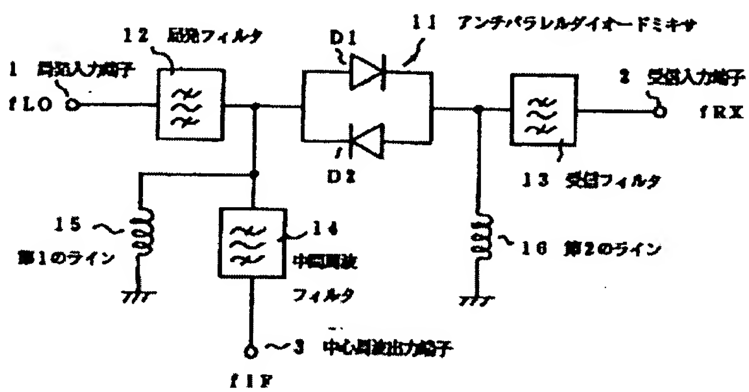
13 reception filter

14 intermediate frequency filter

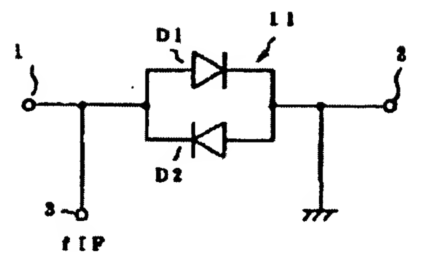
15 first line

16 second line

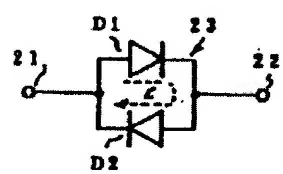
[FIG. 1]



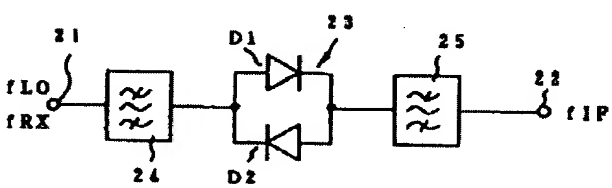
[FIG. 2]



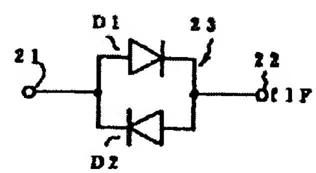
[FIG. 6]



[FIG. 4]



[FIG. 5]



[FIG. 3]